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Progressive taxes, equity, and human capital accumulation in an endogenous growth model with overlapping generations

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Abstract

This paper explores the trade-off between efficiency and intra- and intergenerational equity in an endogenous growth model of an open economy with overlapping generations and human capital accumulation. We demonstrate that progressive taxes hurt long-run growth and exacerbate distortions associated with intergenerational spillovers. However, by raising saving, these taxes strengthen the net foreign asset position.

Keywords: Economic growth; Overlapping generations; Progressive taxes

JEL classification: H21; O40

1. Introduction

The literature on the trade-off between equity and efficiency has traditionally focused on static distortions in the labor-leisure choice (see, e.g., Mirrlees (1971); Stiglitz (1985)). The same is true for the associated analysis of disincentive effects associated with labor income taxation (see e.g., Hausman (1981); Triest (1994)). When examining the impact of the tax system on intertemporal decisions, the literature has concentrated mainly on the consequences of capital income taxes for

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saving and investment in the form of physical and financial capital (see, e.g., Sandmo (1985); Sinn (1987)). In recent years, however, the literature on endogenous growth has pointed to human capital accumulation as an important engine of growth and as an activity generating positive spillovers. Indeed, in modern economies, most private wealth takes the form of human capital, while disparities in income originate mainly in interpersonal differences in the endowments of human capital. Partly in response to these developments, the literature has started to analyze how labor taxation impacts the accumulation of human capital (see, e.g., Boskin (1975); Kotlikoff and Summers (1979); Rosen (1980); Atkinson and Stiglitz (1980) (chapter 13), Davies and Whalley (1989); Lord (1989); Lucas (1990); Perroni (1993); Nerlove et al. (1993); Trostel (1993); Nielsen and Sørensen (1993)).

This paper contributes to this literature in four major ways. First, in examining the impact of the tax system on human capital, we employ a model that allows growth to be endogenous in the long run, namely the growth model of human capital accumulation due to Lucas (1988). Hence, in contrast to most other models that have been used to explore the impact of taxes on human capital accumulation (see, e.g., Davies and Whalley (1989); Lord (1989); Perroni (1993); Nerlove et al. (1993); Trostel (1993)), our model allows tax policy to affect long-run growth rates. King and Rebelo (1990); Lucas (1990); Sørensen (1993); Pecorino (1993) also adopt an endogenous growth approach; these studies concentrate on the impacts of flat labor taxes and consumption taxes.

The second major contribution of this paper is to model progressive taxation of labor incomes. The literature on the impact of labor taxation on human capital accumulation has typically assumed proportional labor taxes.[1] Such taxes do not affect the accumulation of human capital if the opportunity costs of learning take the form of foregone earnings subject to labor income tax.[2] The reason is that the costs of learning can effectively be expensed immediately. Accordingly, just as a cash-flow tax (which allows immediate expensing of investment) does not distort investment in physical capital, so does a proportional labor income tax leave unaffected investment in human capital. In this paper, we explore whether this result continues to hold if a progressive tax system causes marginal rates to rise with income. In the absence of overlapping generations, we find that progressive taxes are still neutral unless the government allows the economy-wide tax rate to

[1]For an exception, see Nielsen and Sørensen (1993). This paper employs an exogenous growth model to demonstrate that, in the presence of an exogenous capital income tax, progressive labor taxation may be optimal in order to alleviate distortions in the allocation of the household portfolio over financial and human capital.

[2]Proportional labor taxes do affect the accumulation of human capital if the costs associated with these investments take the form of untaxed leisure (see Rosen (1980); Atkinson and Stiglitz (1980) (chapter 13), Lucas (1990)). Moreover, even in the absence of labor supply effects, these taxes impact growth if any input into human capital accumulation is taxed or produced in a taxed sector (see King and Rebelo (1990); Trostel (1993); Pecorino (1993)).

increase with the real fiscal drag that a progressive tax system produces in a growing economy.

This brings us to the third contribution of this paper, namely the incorporation of overlapping generations in an endogenous growth model with human capital. In particular, we combine into a single consistent framework the endogenous growth model of human capital accumulation due to Lucas (1988) and the overlapping-generations model first developed by Yaari (1965) and later popularized by Blanchard (1985). We show that the introduction of overlapping generations generally renders progressive taxation non-neutral with respect to the decision to invest in human capital, even if the government keeps the aggregate tax rate constant. Intuitively, with overlapping generations, progressive taxes decrease the expected growth of after-tax wages by transferring resources to generations that are yet to be born. This reduces the marginal value of accumulating additional human capital, thereby harming the incentives to invest. The incorporation of overlapping generations allows us to investigate also how tax policies impact the intergenerational distribution of resources.[3] Moreover, the macroeconomic implications for saving and the balance of payments associated with these changes in the intergenerational distribution can be explored.

Our final contribution is to model not only *inter-* but also *intra*generational disparities in labor incomes due to different endowments of human capital. This serves to formalize the trade-off between equity, efficiency, and growth in a dynamic framework with overlapping generations.[4] Indeed, the differences in before-tax labor incomes originating in different endowments of human capital provide a case for progressive labor taxation. We show, however, that a progressive tax can be quite costly, not only in terms of growth but also in terms of efficiency. In particular, without government intervention, intergenerational spillovers of human capital imply that households do not invest enough in human capital. By reducing these investment incentives further, a progressive tax exacerbates the distortions associated with these spillovers.

The rest of this paper is structured as follows. Section 2 presents the model, starting with individual household behavior and moving to aggregate variables describing macroeconomic behavior. Section 3 explores how policy reforms involving the progressivity of labor taxes and lump-sum transfers affect long-run

[3] For a seminal contribution on tax incidence, see Harberger (1962).

[4] There is an extensive literature on the relationship between growth and income inequality. Persson and Tabellini (1992); Alesina and Rodrik (1991) focus on the political aspects, and argue that inequality may hamper growth because the poor vote for high taxes on capital income. Perotti (1990); Garcia-Peñalosa (1995), in contrast, maintain that inequality may be necessary in the early stages of development because it allows the rich to invest in human capital. Tamura (1991); Galor and Tsiddon (1994) address the problem of divergence in income distribution in the presence of human capital externalities and heterogeneous learning capabilities. Glomm and Ravikumar (1992) focus on how inequality influences the choice between a public and private education system. They argue that public education accelerates growth.

growth. How these reforms impact the (intra- and intergenerational) distribution of welfare is investigated in Section 4. Section 5 analyzes the macroeconomic effects on economy-wide saving and net foreign assets. Section 6 concludes by making some observations about Pareto improving reforms.

2. The model

2.1. Production

The production function features constant returns in labor and capital. Capital is perfectly mobile internationally. Accordingly, the small open economy faces a fixed world rate of interest, r, which is constant over time. With perfect competition in factor markets, this interest rate determines the capital intensity of production and hence the before-tax wage rate per effective unit of labor of unit, w.

2.2. Overlapping generations

In modelling overlapping generations, we follow the Yaari–Blanchard approach (see Yaari (1965); Blanchard (1985)). In particular, each household faces a common and constant probability of passing away η. At the same time, households are born at a rate η. The population thus remains constant at a normalized size of unity. Accordingly, the cohort born at time υ features a size, as of time t, of $\eta e^{-\eta(t-\upsilon)}$.

At each moment in time, t, a household born at time $\upsilon<t$ maximizes expected intertemporal utility:

$$\int_{t}^{\infty} \frac{1}{1-\sigma} c_i(\upsilon,s)^{1-\sigma} e^{-(\eta+\rho)(s-t)} \mathrm{d}s \tag{1}$$

where $c_i(\upsilon,s)$ denotes the consumption at time s of household i in the cohort born at time υ. The effective discount rate amounts to the sum of the subjective rate of discount, ρ, and the probability of death, η.

Households can accumulate not only financial capital (as in Yaari (1965); Blanchard (1985)) but also human capital. Following Lucas (1988), the accumulation of human capital is determined by learning activities. Households divide total available time, which is normalized at unity, between time spent learning $x_i(\upsilon,t)$ and time spent working in production $(1-x_i(\upsilon,t))$. The growth rate $g_i(\upsilon,t)$ at time t of human capital of an agent i, born at time υ, $h_i(\upsilon,t)$, is given by

$$g_i(\upsilon,t) \equiv \frac{\dot{h}_i(\upsilon,t)}{h_i(\upsilon,t)} = \phi(x_i(\upsilon,t)) \quad \phi'>0,\ \phi''<0 \tag{2}$$

where a dot above a variable stands for the time derivative.

Financial wealth of this household, $a_i(v,t)$, accumulates according to the following flow budget constraint

$$\dot{a}_i(v,t) = (r+\eta)a_i(v,t) + \omega_i(v,t)(1-x_i(v,t))h_i(v,t) + \theta(t)H(t) - c_i(v,t) \quad (3)$$

where $\theta(t)H(t)$ represents lump-sum transfers, which are uniform across all households alive at any point in time, $H(t)$ denotes average human capital (see Eq. (15) below), and $\omega_i(v,t)$ stands for the after-tax wage, which is specific to each household. Competitive life insurance companies promise households a yearly payment in exchange for having the estate accruing to these companies. In the absence of a bequest motive and in the presence of a competitive and efficient annuities market, households invest their entire financial wealth in these annuities. Accordingly, households collect a return on financial wealth consisting of not only the world rate of interest, r, but also an annuity payment, η.

Newly born households begin their lives without any financial capital because the estates of those passing away accrue to life insurance companies:

$$a_i(v,v) = 0 \quad (4)$$

However, the young are born with some human capital, which depends on the level of average human capital ('state of knowledge') that is present in the economy at the time of birth. In particular, newly born households 'inherit' a random fraction of the average level of human capital[5] in the economy

$$h_i(v,v) = \chi_i H(v) \quad \chi_i \in [\underline{\chi},\bar{\chi}],\ \chi_i \sim \pi(\chi_i) \quad (5)$$

where the variable χ_i is distributed randomly over the interval $[\underline{\chi},\bar{\chi}]$ with density function $\pi(\chi_i)$.[6] In addition to *intra*generational inequities due to the variance of χ_i, we allow for *inter*generational heterogeneity in human capital originating in the expected value of that random variable χ_i. In particular, on average, newly born generations inherit less than average human capital, i.e., $\chi \equiv E(\chi_i) < 1$.

In contrast to Lucas (1988), we abstract from intragenerational externalities. However, our specification of the transfer of human capital across generations implies intergenerational externalities. In particular, by accumulating human capital, households boost the average level of human capital, thereby raising the level of human capital that newly born households inherit (see Eq. (5)). In this way, learning confers positive externalities on future generations.

[5]Galor and Tsiddon (1994) assume that the human capital of the newly born depends on the human capital of the parents rather than on the average level of human capital. Their formulation may give rise to persistent inequalities.

[6]Productivity cannot be negative, $\underline{\chi} \geq 0$.

2.3. Progressive taxes

Wages are subject to a progressive labor income tax. In particular, residual income progressivity δ (≤ 1) is constant[7] along the entire tax schedule:

$$1-\delta=\frac{1-\tau_i^m(v,t)}{1-\tau_i^a(v,t)} \quad \forall\, i, v, t \tag{6}$$

where $\tau_i^a(v,t)$ represents the average tax rate facing agent i of generation v at time t:

$$1-\tau_i^a(v,t)\equiv \omega_i(v,t)/w \tag{7}$$

and $\tau_i^m(v,t)$ denotes the corresponding marginal tax rate. Positive residual income progressivity (i.e. $\delta>0$) implies that the marginal tax rate exceeds the average rate. With constant residual income progressivity, after-tax wage income can be written as

$$\omega_i(v,t)(1-x_i(v,t))h_i(v,t)=(1-\tau(t))[w(1-x_i(v,t))h_i(v,t)]^{1-\delta} \tag{8}$$

2.4. Individual optimization and individual growth

Each household selects consumption and learning so as to maximize expected utility (Eq. (1)) subject to the learning function (Eq. (2)) and the budget constraint (Eq. (3)). In addition to the well-known Ramsey rule characterizing the optimal consumption path

$$\dot{c}_i(v,t)=\frac{1}{\sigma}(r-\rho)c_i(v,t), \tag{9}$$

the following optimality conditions describe the optimal amount of learning (see Appendix A):

$$(1-\delta)\omega_i(v,t)=(1-\delta)m_i(v,t)\phi'(x_i(v,t)) \tag{10}$$

$$\dot{m}_i(v,t)=(r+\eta-\phi(x_i(v,t))-(1-x_i(v,t))\phi'(x_i(v,t)))m_i(v,t) \tag{11}$$

where $m_i(v,t)$ represents the average value of human capital (see Appendix A):

[7] Interpreting lump-sum transfers as a refundable tax credit, one can include lump-sum transfers in the definition of after-tax wage income (i.e., $\hat{\omega}_i \equiv \omega_i + \theta H/(1-x_i)h_i$, where $\hat{\omega}_i$ is the alternative definition of after-tax labor income including transfer income). In that case, residual income progressivity $\hat{\delta}$ is not constant but given by:

$$1-\hat{\delta}=(1-\delta)[1+\theta H/(\omega_i h_i(1-x_i))]^{-1}$$

Hence, a positive tax credit (i.e. $\theta>0$) makes the tax system more progressive. At the same time, residual income progressivity decreases with after-tax income of the individual household, $\omega_i h_i(1-x_i)$.

$$m_i(v,t) = \frac{1}{h_i(v,t)} \int_t^{\infty} \omega_i(v,s)(1 - x_i(v,s))h_i(v,s)e^{-\int_t^s (r(u)+\eta)\mathrm{d}u} \mathrm{d}s \tag{12}$$

Eq. (10) equates marginal costs and benefits of learning. The left-hand side represents the marginal costs (i.e. wages foregone), while the right-hand side stands for the marginal benefits (i.e. the marginal value of the additional human capital generated by learning).

In order to interpret Eq. (11), we eliminate the time derivative of the average value of human capital by differentiating (Eq. (10)) with respect to time and using Eq. (8) to find the growth rate of the after-tax wage:

$$r + \eta = \left[(1 - \delta)\phi(x) - \frac{\dot{\tau}}{(1 - \tau)} + \left(\frac{\delta}{1 - x} - \frac{\phi''(x)}{\phi'(x)} \right) \dot{x} \right] + [(1 - x)\phi'(x)]. \tag{13}$$

This expression represents arbitrage between the return on financial capital (i.e. the left-hand side) and the return on human capital (i.e. the right-hand side). The latter return consists of the growth in after-tax wage income (the term in the first square brackets at the right-hand side of Eq. (13)) and the additional growth of the stock of human capital net of the costs of learning in terms of labor foregone (the term in the second square brackets at the right-hand side of Eq. (13)).

The second-order conditions require that the return on human capital declines with learning x. This implies that learning declines if a higher return on financial capital makes investing in financial capital more attractive than investing in human capital.

Neither the return on financial capital nor the return on human capital depends on the initial stocks of human and financial capital. Accordingly, all households, irrespective of their endowments of human and financial capital, select the same amount of learning, $x(t)$. Hence, the growth rate of human capital, $g(t)$, is uniform across households (see Eq. (2)). We can thus relate individual human capital to aggregate human capital as follows:

$$h_i(v,t) = \chi_i H(t) e^{\int_v^t g(s) - n(s)\mathrm{d}s} \tag{14}$$

where $n(t) = \dot{H}(t)/H(t)$ denotes the growth rate of aggregate human capital.

2.5. Aggregate and individual growth of human capital

Aggregation of individual human capital yields average human capital, $H(t)$:

$$H(t) = \int_{-\infty}^{t} \int_{\underline{\chi}}^{\bar{\chi}} \pi(\chi_i) h_i(v,t) \eta e^{-\eta(t-v)} \, \mathrm{d}\chi_i \mathrm{d}v. \tag{15}$$

Substituting Eq. (14) into Eq. (15) to eliminate $h_i(v,t)$, we obtain:

$$H(t) = \int_{-\infty}^{t} \chi H(t)\eta e^{-\int_{v}^{t} \eta - g(s) + n(s)\,\mathrm{d}s}\,\mathrm{d}v \tag{16}$$

Differentiating Eq. (16) with respect to time, we arrive at a relationship between the average and individual growth rates of human capital:

$$g(t) - n(t) = (1 - \chi)\eta. \tag{17}$$

Whereas the generations that pass away feature the average amount of human capital, a typical newly born generation inherits only less than the average amount of capital (i.e. $\chi<1$). Accordingly, the turnover of households due to birth and death results in a net loss of human capital, represented by the right-hand side of Eq. (17). This net loss depresses the average growth of human capital, $n(t)$, below the individual growth rate, $g(t)$. Individual and average growth of human capital coincide (i.e. $g(t)=n(t)$) in both the Yaari–Blanchard model (which does not include human capital accumulation) and the Ramsey model (which does not include overlapping generations). In the Yaari–Blanchard model, new households inherit the average amount of human capital (i.e. $\chi=1$). In the traditional Ramsey model, the birthrate is zero (i.e. $\eta=0$). In our model, the gap between individual and average growth is constant through time because it depends only on the birth rate, η, and the average inheritance parameter χ. Hence, the relationship between individual and average human capital (see Eq. (14)), can be written in a particularly simple form:

$$h_i(v,t) = \chi_i H(t) e^{(1-\chi)\eta(t-v)}. \tag{18}$$

Intragenerational inequities are represented by the term χ_i. The exponential term reflects intergenerational inequities: older generations on average feature more human capital than do younger generations.

2.6. Aggregate tax revenues

The average tax rate, T, is defined by

$$(1 - T(t))(1 - x(t))wH(t) = \int_{-\infty}^{t} \int_{\underline{\chi}}^{\bar{\chi}} \pi(\chi_i)(1 - x(t))\omega_i(v,t)h_i(v,t)\eta e^{-\eta(t-v)}\,\mathrm{d}\chi_i\,\mathrm{d}v. \tag{19}$$

Substituting Eqs. (8) and (18) to eliminate, respectively, after-tax wages and individual human capital, we find

$$(1 - T(t))w = \kappa\omega(t) \tag{20}$$

where $\omega(t) \equiv (1-\tau(t))[(1-x(t))wH(t)]^{-\delta}w$ represents the after-tax wage rate of a household with average human capital (substitute $h_i(v,t) = H(t)$ into Eq. (8)) and where

$$\kappa \equiv \left[\int_{\underline{\chi}}^{\bar{\chi}} \pi(\chi_i) \left(\frac{\chi_i}{\chi} \right)^{1-\delta} \mathrm{d}\chi_i \right] \left[\frac{\chi^{1-\delta}}{\delta + \chi - \delta\chi} \right]. \tag{21}$$

The term κ reflects the impact of a progressive tax system on tax revenues. This factor is smaller than unity if the tax system is progressive (i.e. $\delta > 0$) and households are heterogenous (i.e. $\exists \chi_i \neq 1$). Intuitively, a progressive tax system implies that the additional revenues collected from the rich exceed the loss of tax revenues from the poor. This implies that, for a given average tax burden T, the tax paid by an agent with average human capital can be reduced, thereby boosting the after-tax income of this agent. In other words, with a progressive tax system, the average tax burden (i.e. T) exceeds the tax burden on the average household (i.e. $(w-\omega)/w$).

The two terms in square brackets at the right-hand side of Eq. (21) represent the two sources of inequity. The term in the first square brackets stems from *intra*generational heterogeneity, while the term in the second square brackets represents the effect of *inter*generational inequality. These inequities cause the average tax burden to rise above the tax burden on the household with average human capital only if the tax system is progressive. Indeed, with zero residual income progressivity (i.e. $\delta = 0$), both terms at the right-hand side are unity.

2.7. Aggregate consumption and wealth

We define any aggregate variable in analogy of the definition for human capital (see Eq. (15)). Moreover, to arrive at a stable dynamic system in our endogenous growth model, we write all aggregate variables as a ratio to aggregate human capital, $H(t)$.

Aggregating individual consumption, we find that aggregate consumption, $C(t)$, is a fixed fraction,

$$\gamma = r + \eta - \frac{1}{\sigma}(r - \rho) \tag{22}$$

of aggregate wealth (see Appendix B):

$$C(t) = \gamma V(t) \tag{23}$$

Aggregate wealth, $V(t) = A(t) + Z(t) + \Theta(t)$, consists of financial, human, and transfer wealth, where $A(t)$ represents aggregate financial wealth (as a ratio to human wealth, $H(t)$), $Z(t)$ denotes the average value of human capital, and $\Theta(t)$ stands for the present value of transfers (as a fraction of human wealth, $H(t)$):

$$\Theta(t) = \int_t^{\infty} \theta(s)\, e^{-(r+\eta-n)(s-t)}\, ds. \tag{24}$$

The aggregate household budget constraint, which corresponds to the individual constraint (Eq. (3)), describes the accumulation of economy-wide financial wealth:

$$\dot{A}(t) = (r - n(t))A(t) + (1 - T(t))(1 - x(t))w + \theta(t) - C(t). \tag{25}$$

Whereas annuity payments supplement individual wealth (see Eq. (3)), they do not add to aggregate wealth because they constitute a transfer from those who pass away to those who remain alive. Consequently, individual wealth accumulates faster than aggregate wealth does.

The average value of human wealth, $Z(t)$, is defined as follows:

$$Z(t) \equiv \frac{1}{H(t)} \int_{-\infty}^{t} \int_{\underline{\chi}}^{\bar{\chi}} \pi_i(\chi_i) h_i(v,t) m_i(v,t) \eta\, e^{-\eta(t-v)}\, d\chi_i\, dv. \tag{26}$$

Noting that $m_i(v,t)/\omega_i(v,t)$ is the same for all generations (since all households select the same amount of learning $x(t)$, see Eq. (10)), and using Eq. (19), we can write $Z(t)$ as:

$$Z(t) = (1 - T(t))w(t)\frac{m_i(v,t)}{\omega_i(v,t)}. \tag{27}$$

Hence, we can write the first-order condition for learning (Eq. (10)) in terms of aggregate variables:

$$(1 - T(t))w(t) = Z(t)\phi'(x(t)). \tag{28}$$

Moreover, by using Eq. (20) to eliminate the aggregate tax rate from Eq. (27) and differentiating the result with respect to time, we find:

$$\frac{\dot{Z}(t)}{Z(t)} = \frac{\dot{m}_i(v,t)}{m_i(v,t)} + \delta(g(t) - n(t)). \tag{29}$$

Using Eq. (29) to eliminate $\dot{m}_i(v,t)/m_i(v,t)$ from Eq. (11), and substituting Eqs. (2), (17) and (28), we write also the arbitrage condition in aggregate form:

$$\dot{Z}(t) = [r - n(t) + \eta\chi + \delta\eta(1 - \chi)]Z(t) - (1 - x(t))(1 - T(t))w. \tag{30}$$

In the presence of overlapping generations (i.e. $\eta>0$) and the absence of progressive taxes (i.e. $\delta=0$), aggregate human capital features a higher return compared to aggregate financial capital (compare the terms in Eqs. (30) and (25) in front of, respectively, $Z(t)$ and $A(t)$ where $r-n(t)+\eta\chi>r-n(t)$). Intuitively, whereas agents are compensated by the insurance contract for the loss of financial capital at death, they lose their human capital when they pass away. The associated implicit tax on human capital causes the required return on human capital to exceed the return on financial capital.

Differentiating Eq. (23) with respect to time, using $V(t)=A(t)+Z(t)+\Theta(t)$, eliminating Θ and eliminating $\dot{A}$, $\dot{Z}$ and $\dot{\Theta}$ from Eqs. (25), (30) and (24) respectively, we find the following dynamic equation for C:

$$\dot{C}(t)=\left(\frac{1}{\sigma}(r-\rho)-n(t)\right)C(t)-\gamma\eta A(t)-\gamma\eta(1-\delta)(1-\chi)Z(t). \tag{31}$$

The first term at the right-hand side of Eq. (31) represents individual growth of consumption (compare Eq. (9)).[8] In the absence of overlapping generations (i.e. $\eta=0$), individual and aggregate growth coincide. In the presence of overlapping generations (i.e. $\eta>0$), however, the last two terms on the right-hand side of Eq. (31) represent the impact on aggregate consumption growth of the turnover of generations with different levels of wealth. In particular, the second term on the right-hand side of Eq. (31) involves intergenerational differences in the ownership of financial capital. If aggregate financial wealth is positive (i.e. $A(t)>0$), the older generations that pass away own more financial wealth than the newly born, who begin their lives without any financial wealth (see Eq. (4)). The replacement of richer, older generations by poorer, younger generations reduces the aggregate growth rate of consumption below the individual growth rate.

In the traditional Yaari–Blanchard model (i.e. $\chi=1$), only the first two terms appear. The reason is that newly born generations inherit the average amount of human capital so that all generations feature the same endowment of human capital. Accordingly, at any point in time, financial wealth is the only component of wealth that is distributed unequally across the generations. In our model, in contrast, the newly born inherit on average less human capital than is owned by the generations that pass away. The birth of households that are relatively poorly endowed with human capital depresses the growth rate of economy-wide consumption further below individual consumption growth. Only if a progressive tax system (i.e. $\delta=1$) completely eliminates differences in before-tax labor incomes, does the third term drop out. Indeed, by narrowing intergenerational differences in

[8] The term $-n(t)C(t)$ appears in Eq. (31) because C is measured as a ratio to aggregate human wealth, which grows at rate $n(t)$.

after-tax incomes, a progressive tax system reduces the importance of the third term.[9]

3. Taxes and growth

To find the solution for the growth rate, we substitute the time derivative of Eq. (28) to eliminate $(\dot{Z}/Z)$ from Eq. (30). Using Eqs. (28) and (17), we arrive at:

$$-\frac{\phi''(x)}{\phi'(x)}\dot{x} = r + \eta - \phi(x) + \delta\eta(1-\chi) - g_T - (1-x)\phi'(x) \tag{32}$$

where $g_T \equiv \frac{1}{1-T}\frac{\mathrm{d}(1-T)}{\mathrm{d}t}$. With a constant growth rate of the tax factor g_T, the long-run growth rate is constant (i.e. $\dot{x}=0$) only if:

$$r + \eta = g_\omega + (1-x)\phi'(x) \tag{33}$$

where $g_\omega \equiv g - \delta\eta(1-\chi) + g_T = n + \eta(1-\delta)(1-\chi) + g_T$ is the steady-state growth of after-tax wages of an individual household. This arbitrage condition between the return on financial capital (on the left-hand side of Eq. (33)) and the return on human capital (on the right-hand side of Eq. (33)) determines the growth rate. In order to exclude explosive behavior of x, this arbitrage condition must hold not only in the long run but also in the short run. Hence, following a change in progressivity, the growth rate jumps immediately to its new long-run equilibrium value. Indeed, by using Eq. (2), we can determine from Eq. (33) the (short- and long-run) growth effect of a more progressive tax system (while keeping the growth rate of the aggregate tax burden (i.e. g_T) constant):

$$\frac{\mathrm{d}g}{\mathrm{d}\delta} = -\frac{1}{\sigma_g}\eta(1-\chi); \quad \text{where} \quad \sigma_g = -\frac{(1-x)\phi''(x)}{\phi'(x)} > 0. \tag{34}$$

A more progressive tax system implied by a higher (constant) residual rate of income progressivity harms growth only if overlapping generations are present (i.e. $\eta>0$) or if the growth rate of the aggregate tax rate on wages is allowed to change (i.e. $g_T<0$). Intuitively, with progressive taxes in a growing economy, the government can keep the average tax burden from rising faster only by gradually reducing the tax rate $\tau(t)$ (see Eq. (8)). Without overlapping generations (i.e. $\eta=0$) and with constant residual income progressivity rate, the positive effect of the anticipated drop in the tax rate on the expected growth rate of after-tax wages exactly offsets the adverse impact of the progressive tax system on the growth of

[9] At the right-hand side of Eq. (31), the term in front of financial capital exceeds the term in front of human capital (if $\delta \geq 0$). The reason is that newborn agents are born with positive human capital (i.e. $\chi>0$) but without any financial capital. Accordingly, the turnover of overlapping generations depresses the growth of financial capital more than it reduces the growth of human capital.

after-tax wages. Hence, the incentives for learning, which depend on the growth of after-tax wages, are unaffected. Intuitively, if generations do not turn over, the growth dividend to the public budget due to a progressive tax system (the so-called 'real fiscal drag') is returned to the same agents.[10]

This is no longer the case if overlapping generations open up the possibility of intergenerational transfers. In particular, progression implies a relatively small growth rate of aggregate tax revenues if the birth of new generations, which are relatively poorly endowed with human capital ($\chi<1$), depresses aggregate wage growth. Consequently, the direct adverse impact of progression on expected growth of after-tax wages (which depends on individual growth, g) dominates the indirect positive impact due to the decline in the tax factor required to keep the aggregate tax burden constant (which depends on aggregate growth, n). Intuitively, a progressive tax system transfers resources from the richer, older generations to the poorer, newly born generations, thereby reducing the growth of after-tax wages and thus harming the incentives to learn.

Even in the absence of overlapping generations, progressivity harms growth if the real fiscal drag is returned in the form of transfers rather than lower labor tax rates τ (i.e. $dg_T/d\delta>0$). In that case, a more progressive tax burden boosts the growth rate of the average tax burden for the economy as a whole. This implies that all households face an increasing tax burden over time, thereby harming the incentives to accumulate human capital.

To provide more intuition for the adverse effect of progression on growth, we write the first-order condition for learning (Eq. (10)) by using Eq. (33) as follows:

$$(1-\delta)\omega_i = (1-\delta)\phi'(x)\,\frac{(1-x)\omega_i}{r+\eta-g_\omega}. \tag{35}$$

The left-hand side represents the marginal costs of devoting one additional unit of time to learning (i.e. loss of labor income), whereas the right-hand side stands for the marginal benefits of learning in terms of additional human capital. The terms $(1-\delta)$ on both sides of the equation cancel because a more progressive tax system

[10] In the absence of not only intergenerational but also intragenerational heterogeneity, this result is independent of the form of progressivity assumed; without any heterogeneity among agents, a constant growth rate of the economy-wide average tax burden on wages implies that also the representative agent faces a constant growth rate of the average tax burden. With intragenerational heterogeneity, however, more progressive taxes may impact growth by affecting the individual growth rate of the tax burden—even if the growth rate of the average tax rate for the economy as a whole is kept constant. We have excluded this possibility by assuming that residual income progressivity is constant and that revenues are returned in the form of a lower tax rate τ. Under these assumptions, a constant growth rate of the average tax burden for the economy as a whole implies that the growth rate of the average tax burden for each individual household is constant as well. Of course, a change in progressivity differentially affects the level (as opposed to the growth rate) of the average tax burden of households with different abilities (see Section 4.2).

reduces both the marginal costs of learning in the form of foregone earnings and the marginal benefits of learning in the form of additional future earnings. The adverse effect of progression on growth thus works through the marginal value of human capital, $m_i = (1-x)\omega_i/(r+\eta-g_\omega)$ (see Eq. (10)). In particular, with individual growth exceeding average growth (i.e. $g-n>0$), a progressive tax system causes each household to face a rising tax burden over time because of the transfer of resources to poorer, newly born generations. The adverse effect of progression on the growth rate of after-tax wages depresses the value of each additional unit of human capital, thereby discouraging learning.

Neither the level of the aggregate tax rate, T, nor lump-sum transfers, θ, enter Eq. (33). Hence, these variables do not affect the growth rate. The reason is that lump-sum transfers do not affect marginal decisions. The level of the tax burden reduces both the marginal costs of learning (i.e. wages foregone) and the marginal benefits (i.e. future wages). These two effects exactly offset each other so that the tax burden leaves growth unaffected. Intuitively, with respect to the accumulation of human capital, the labor income tax acts like a cash-flow tax with immediate depreciation of investment costs.

4. Distributional consequences of tax reforms

This section explores the impact of changes in policy on the intra- and intergenerational distribution of resources. These distributional impacts are of interest in themselves. Moreover, by affecting saving behavior, they yield macroeconomic implications for the external account (see Section 5). We explore the distributional effects of changes in not only the residual rate of income progressivity (Section 4.2) but also lump-sum transfers (Section 4.3). The distributional effects of this latter policy instrument are analyzed because it can be interpreted as an alternative way of making the tax system more progressive (see footnote 7). Moreover, this instrument can be employed to offset the undesirable distributional impacts of a regressive tax system, which internalizes the positive intergenerational externalities associated with learning (see Section 6 and Bovenberg and van Ewijk (1995)).

4.1. The measurement of welfare

With a fixed interest rate, welfare effects are proportional to changes in individual wealth. Individual wealth of generations alive at the time of the policy shock, t, (the 'current' generations) is given by:

$$V_i(v,t) = \frac{a_i(v,t)}{H(t)} + Z(t)\Omega_i(v,t) + \Theta(t) \tag{36}$$

where $V_i(v,t)$ denotes the wealth (scaled by $H(t)$) of a household with age

$t - v \geq 0$, where v denotes the time of birth. Ω_i (which is found by using Eqs. (8), (20) and (27)) indicates the relative position of this household in the distribution of human wealth of present generations:

$$\frac{1}{\kappa}\underline{\chi}^{1-\delta} \leq \Omega_i(v,t) \equiv \frac{1}{\kappa}\left(\frac{h_i(v,t)}{H(t)}\right)^{1-\delta} < \infty \quad v \leq t. \tag{37}$$

Using Eqs. (18) and (21) to eliminate κ and $h_i(v,t)$, we find:

$$\Omega_i(v,t) = (\chi + \delta - \chi\delta)\beta_i\, e^{\eta(1-\chi)(1-\delta)(t-v)} \tag{38}$$

where

$$\beta_i \equiv \frac{\chi_i^{1-\delta}}{\int_{\underline{\chi}}^{\bar{\chi}} \pi(\chi_i)\chi_i^{1-\delta}\mathrm{d}\chi_i}. \tag{39}$$

The generations that are yet to be born (i.e. the 'future' generations) begin their lives without any financial wealth (see Eq. (4)). The human capital at birth of a generation born at time $v > t$ amounts to $\chi_i H(v)$ (see Eq. (5)). Accordingly, their wealth at birth (scaled by $H(t)$) amounts to

$$V_i^F(v,t) = [Z(v)\Omega_i^F + \Theta(v)]\, e^{n(v-t)} \quad v \geq t \tag{40}$$

where

$$\Omega_i^F = \frac{1}{\kappa}\chi_i^{1-\delta} = \beta_i(\chi + \delta - \chi\delta). \tag{41}$$

The government keeps both the average tax rate, T, and the ratio of transfers to human capital, θ, constant through time. This implies that both the average value of human capital, Z, and transfer wealth, Θ, are constant at:

$$Z = (1 - T)(1 - x)w/\psi \tag{42}$$

$$\Theta = \theta/(r + \eta - n) \tag{43}$$

where $\psi \equiv r + \eta - g_\omega$ and the growth of after-tax wages $g_\omega = g - \delta\eta(1-\chi)$. Thus, the average value of human capital corresponds to the average value of after-tax wage income, $(1-T)(1-x)w$, discounted by the interest rate and the probability of death, $r + \eta$, net of the growth rate of after-tax wages, g_ω.

4.2. Distributional consequences of a more progressive tax system

To analyze the distributional impact of a more progressive tax system, we assume that the government employs neither debt policy nor lump-sum transfers.

For this case, the government budget constraint (see Eq. (50) below) implies that the aggregate tax burden, T, is zero.

For current generations, changes in progressivity yield the following welfare effect for agent i (see Appendix C):

$$\frac{dV_i(v,t)}{d\delta} = Z\Omega_i(v,t)\left[\frac{\frac{d\beta_i}{d\delta}}{\beta_i} + \frac{(1-\chi)(r-n)}{\psi(\chi+\delta-\chi\delta)} - \eta(1-\chi)(t-v)\right] \quad v \leq t \tag{44}$$

where

$$\frac{\frac{d\beta_i}{d\delta}}{\beta_i} = \frac{\int_{\underline{\chi}}^{\bar{\chi}} [\ln\chi_j - \ln\chi_i]\chi_j^{1-\delta}\pi(\chi_j)d\chi_j}{\int_{\underline{\chi}}^{\bar{\chi}} \chi_j^{1-\delta}\,\pi(\chi_j)\,d\chi_j}. \tag{45}$$

The right-hand side of Eq. (44) reveals that the welfare effect depends on intra- and intergenerational heterogeneity. The first term in the square brackets (i.e. Eq. (45)) represents the impact of intragenerational inequities. Households with relatively low χ_i benefit from a more progressive tax system (i.e. $(d\beta_i/d\delta)>0$). Intergenerational inequities are captured by the second and third terms. Progressive taxes hurt old generations (i.e. $v \to -\infty$) because these generations feature relatively large stocks of human capital. Young generations, in contrast, typically gain. Indeed, without intragenerational inequity (i.e. $(d\beta_i/d\delta)=0$), generations born immediately before the policy shock (i.e. $t-v$ is small) gain unambiguously. In the presence of intragenerational inequity, the young households that are relatively poorly endowed with human capital (i.e. $d\beta_i/d\delta>0$) benefit.

Aggregating welfare losses, we find the impact on aggregate wealth of the currently living:

$$\frac{dV(t)}{d\delta} \equiv \int_{-\infty}^{t}\int_{\underline{\chi}}^{\bar{\chi}} \frac{dV_i(v,t)}{d\delta}\,\pi(\chi_i)\eta\, e^{-\eta(t-v)}\,d\chi_i\,dv = -\frac{\eta(1-\chi)Z}{\psi}. \tag{46}$$

Aggregate wealth declines because progressive taxes redistribute not only within current generations but also away from current towards future generations. The reason is that at any future point in time, $s>t$, current generations (i.e. $v\leq t$) own more human capital than the generations that are alive by then but have been born only after the policy shock (i.e. $t<v<s$). At that future time, s, a progressive tax system transfers resources away from the older, current generations towards the younger, future generations. These future transfers hurt the growth of labor income

that current generations expect, thereby decreasing the value of their human capital. The intergenerational transfers are particularly large if, compared to older generations, younger generations own substantially less human capital (i.e. χ is small) and the birth rate, η, is high.

For future generations, we find that a more progressive tax system produces the following welfare effects for individual households (see Appendix C):

$$\frac{\mathrm{d}V_i^F(v,t)}{\mathrm{d}\delta} = Z\Omega_i^F\, e^{n(v-t)} \left[\frac{\frac{\mathrm{d}\beta_i}{\mathrm{d}\delta}}{\beta_i} + \frac{(1-\chi)(r-n)}{\psi(\chi+\delta-\chi\delta)} + (v-t)\frac{\mathrm{d}g}{\mathrm{d}\delta} \right]$$
$$v > t. \tag{47}$$

As in the welfare expression for current generations (i.e. Eq. (44)), we can identify intra- and intergenerational effects. The first term in the square brackets on the right-hand side of Eq. (47) represents the impact of intragenerational inequity with 'poor' households featuring relatively little human capital benefitting from a more progressive tax system. The second term on the right-hand side of Eq. (47) represents the net transfer from current to future generations described above. Finally, the third term on the right-hand side of Eq. (47) indicates how the stock of human capital inherited by the generation born at time $v > t$ is affected by a change in the growth rate between the time of the policy shock, t, and the time of birth, v. This term is negative because a progressive tax system harms growth (see Eq. (34)). For generations born sufficiently far in the future, this negative growth effect dominates the effects represented by the other two terms at the right-hand side of Eq. (47).

Hence, a progressive tax system hurts both very old, current generations (i.e. $v \to -\infty$) and very young, future generations (i.e. $v \to \infty$) (see Fig. 1). The old lose because progressive taxes harm rich generations featuring high stocks of human capital. The young born far into the future are hurt by the adverse effects of progressive taxes on learning and growth. These losses are particularly large for the households that are relatively well endowed with human capital at birth (i.e. $\chi_i > \chi$).

Aggregating the welfare effects for future generations, we find

$$\frac{\mathrm{d}V^F(t)}{\mathrm{d}\delta} \equiv \int_t^{\infty} \int_{\underline{\chi}}^{\bar{\chi}} \frac{\mathrm{d}V_i^F(v,t)}{\mathrm{d}\delta}\, \pi(\chi_i)\eta\, e^{-r(t-v)}\, \mathrm{d}\chi_i\, \mathrm{d}v$$
$$= Z\eta \left[\frac{(1-\chi)}{\psi} + \frac{(\chi+\delta-\chi\delta)}{(r-n)} \frac{\frac{\mathrm{d}g}{\mathrm{d}\delta}}{(r-n)} \right]. \tag{48}$$

Substitution of Eq. (34) for $\mathrm{d}g/\mathrm{d}\delta$ into Eq. (48) yields

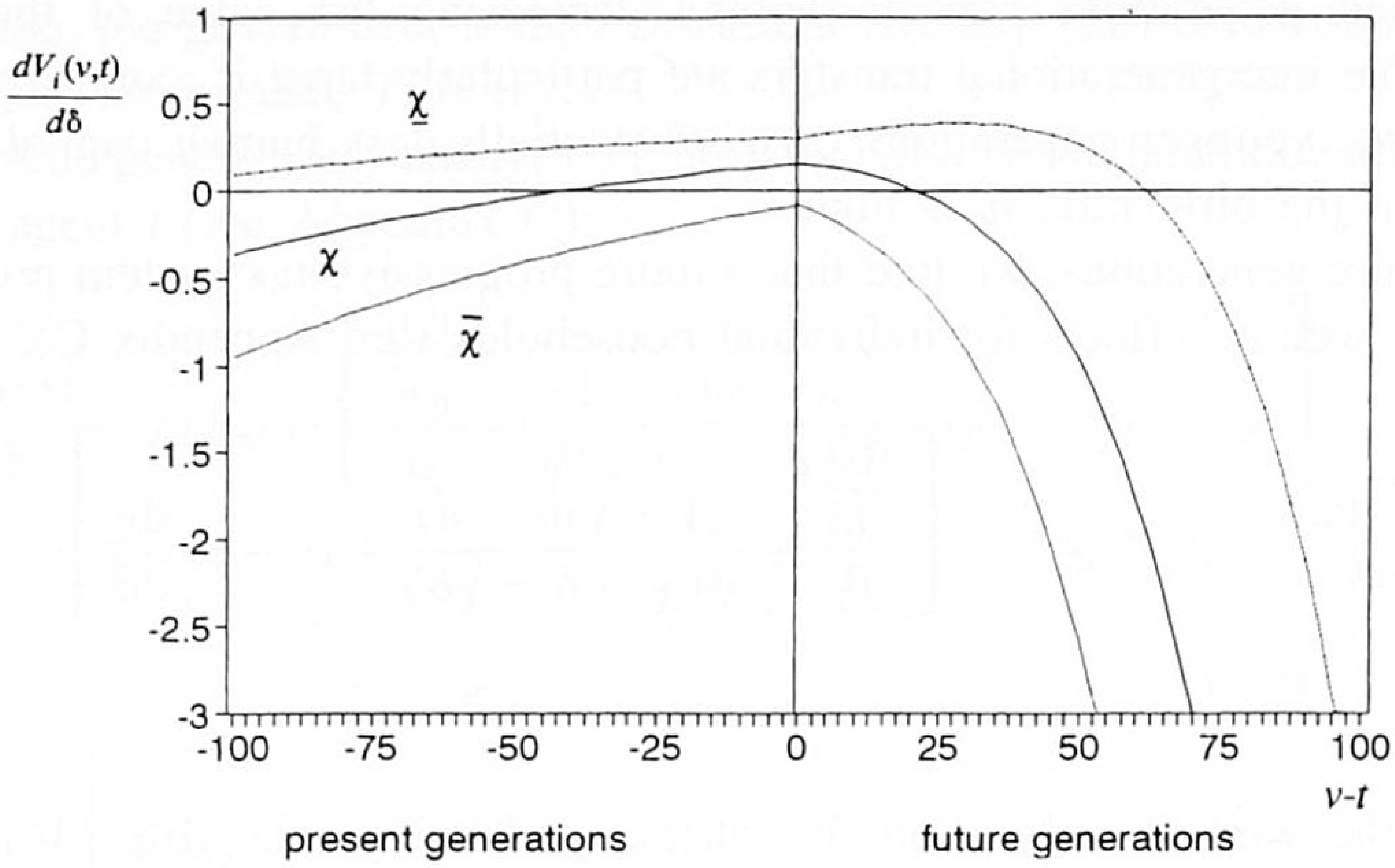

Fig. 1. Distributive impact of progression. This figure is based on the following parameter values, $r=0.05$; $n=0.03$; $\eta=0.02$; $\sigma_g=0.5$; $Z=1$, $\chi=0.75$; $\underline{\chi}=0.75$; $\bar{\chi}=1$.

$$\frac{\mathrm{d}V^F(t)}{\mathrm{d}\delta}=\frac{Z\eta\,(1-\chi)}{\psi}\left[1-\frac{\eta\psi(\chi+\delta-\chi\delta)}{(r-n)^2}\,\frac{1}{\sigma_g}\right]. \tag{49}$$

The two terms on the (last) right-hand side of Eq. (48) stand for intergenerational distributional and efficiency effects, respectively. The intergenerational distributional effect of progressive taxes in favor of future generations is captured by the first term (this term is the negative of the welfare loss of current generations; see Eq. (46)). The second term represents the efficiency losses associated with the fall in the growth rate. These efficiency losses become larger if learning behavior is elastic with respect to changes in progressivity of the tax system (i.e. the elasticity, σ_g, is small – indicating that the efficiency of learning is not very sensitive to changes in learning) and if future generations inherit relatively large amounts of human capital (i.e. the birth rate, η, and the inheritance rate, χ, are large).[11] Changes in the growth rate generate first-order welfare implications only for future generations. The reason is that current generations internalize the benefits of learning on their own welfare.[12] They thus equate the marginal benefits and costs

[11] In fact, non-zero efficiency losses require the presence of both intergenerational spillovers and intergenerational inequities (so that χ needs to lie between one and zero). Without intergenerational spillovers (i.e. $\chi=0$), changes in growth yield no first-order effects on welfare (see Eq. (48)). If intergenerational inequities are absent (i.e. $\chi=1$), a progressive tax system does not reduce growth (see Eq. (34)).

[12] In general, this is no longer true in the presence of initial tax distortions. In that case, changes in behavior, which imply only second-order effects on private welfare, may have first-order implications for aggregate tax revenues and thus social welfare. We have assumed that the aggregate tax burden is zero. In that case, first-order effects on the aggregate tax burden are zero.

of learning so that marginal changes in learning do not affect their welfare. Current generations, however, neglect the positive external effects of learning on the human capital bequeathed to future generations. Hence, an increase in learning, and the associated increase in growth, benefits future generations. The decline in growth produced by more progressivity thus exacerbates the distortions associated with these intergenerational spillovers.

4.3. Distributional effects of transfers financed by wage taxation

To find the welfare impacts of changes in lump-sum transfers financed by labor taxation (keeping δ constant), we impose a balanced budget at each point in time:

$$\theta(t) = T(t)(1-x)w. \tag{50}$$

Substituting Eqs. (42) and (50) into Eq. (36) to eliminate, respectively, Z and T, we find for the effect on welfare of current generations born at time $v \leq t$

$$\frac{\mathrm{d}V_i(v,t)}{\mathrm{d}\theta} = \frac{-\eta(1-\chi)(1-\delta)}{\psi(r+\eta-n)} + \frac{(1-\beta_i)}{\psi} + \frac{\beta_i}{\psi}\left[1-(\chi+\delta-\chi\delta)\, e^{\eta(1-\chi)(1-\delta)(v-t)}\right] \tag{51}$$

and that of future generations born at time $v > t$:

$$\frac{\mathrm{d}V_i^F(v,t)}{\mathrm{d}\theta} = \left[\frac{(1-\chi)(1-\delta)}{\psi(r+\eta-n)}(r-n) + \left(\frac{\chi+\delta-\chi\delta}{\psi}\right)(1-\beta_i)\right] e^{n(v-t)}. \tag{52}$$

The benefits of lump-sum transfers are distributed uniformly across households because the lump-sum transfers are the same for all households and thus depend on neither income nor age. The taxes raised to finance the transfers, in contrast, are borne mostly by those with large stocks of human capital. Accordingly, additional transfers redistribute resources away from those with large stocks of human capital toward those with only little human capital.

Without intragenerational inequities (i.e. $\chi_i = \chi$ and $\beta_i = 1$), age is the only determinant of the distribution of human capital, with older generations featuring the highest stocks of human capital. Consequently, young generations benefit from transfers at the expense of the older generations. In particular, all future generations and the current generations born not long before the policy shock gain unambiguously (see the case with $\chi_i = \chi$ in Fig. 2). Indeed, future generations as a group benefit:

$$\frac{\mathrm{d}V^F(t)}{\mathrm{d}\theta} \equiv \int_t^{\infty}\int_{\underline{\chi}}^{\bar{\chi}} \frac{\mathrm{d}V_i^F(v,t)}{\mathrm{d}\theta}\,\pi(\chi_i)\eta\, e^{-r(t-v)}\,\mathrm{d}\chi_i\,\mathrm{d}v = \frac{\eta(1-\chi)(1-\delta)}{\psi(r+\eta-n)}. \tag{53}$$

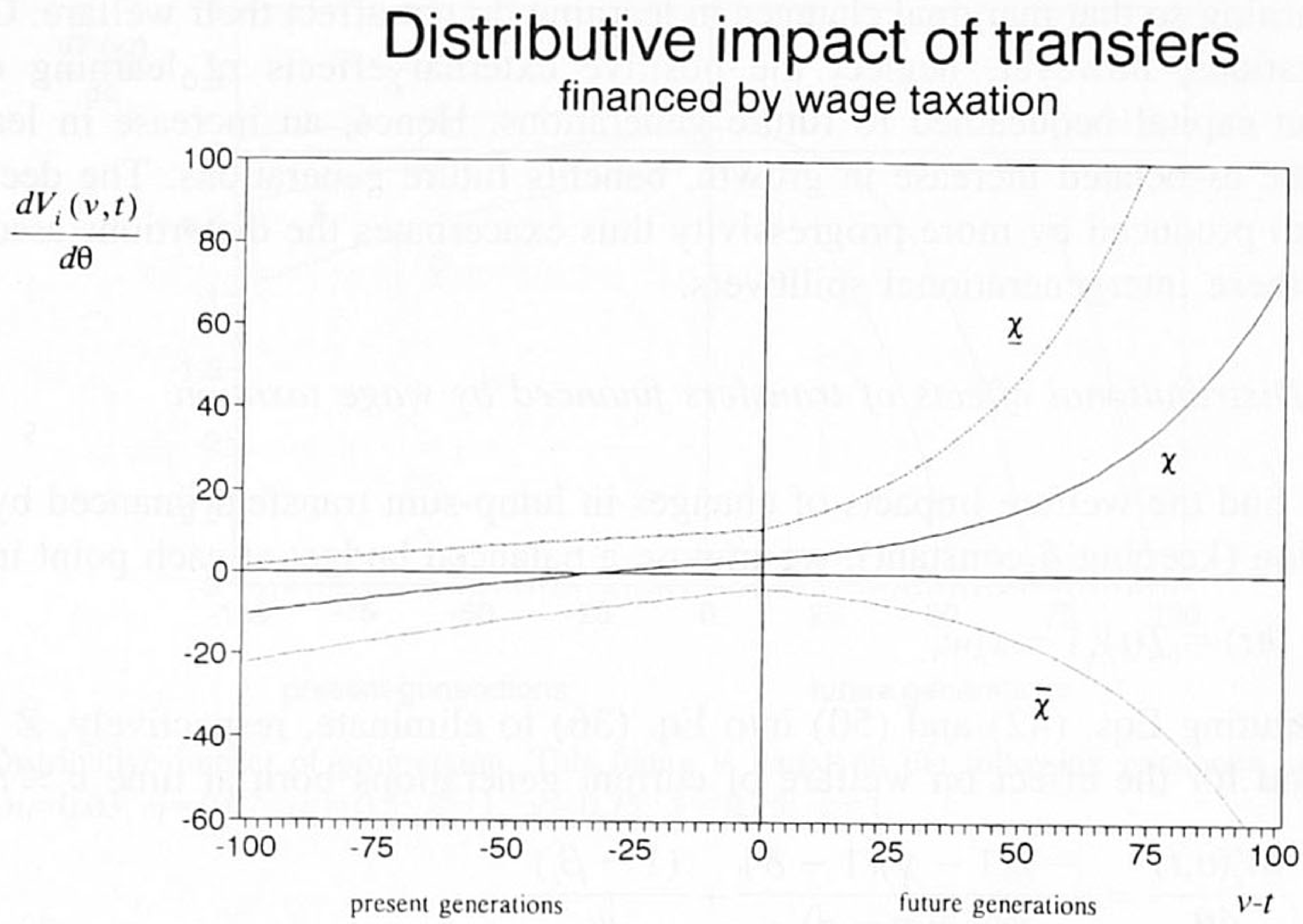

Fig. 2. Distributive impact of transfers financed by wage taxation. Explanation: see Fig. 1.

The aggregate wealth effect for current generations, in contrast, is negative:

$$\frac{\mathrm{d}V(t)}{\mathrm{d}\theta} \equiv \int_{-\infty}^{t} \int_{\underline{\chi}}^{\bar{\chi}} \frac{\mathrm{d}V_i(v,t)}{\mathrm{d}\theta} \pi(\chi_i)\eta\, e^{-\eta(t-v)}\, \mathrm{d}\chi_i\, \mathrm{d}v = -\frac{\eta(1-\chi)(1-\delta)}{\psi(r+\eta-n)}. \tag{54}$$

Hence, in contrast to progressive taxation, lump-sum transfers are purely redistributive: the aggregate gain of future generations corresponds to the aggregate loss of the current generations. Current generations escape a loss in aggregate wealth if no intergenerational inequities exist. This is the case if overlapping generations are absent (i.e. $\eta=0$), the tax system completely equalizes after-tax labor (i.e. $\delta=1$), or intergenerational differences in before-tax labor incomes are absent (i.e. $\chi=1$).

In the presence of intragenerational inequities, age is not the only determinant of the distribution of human capital. If intragenerational inequities dominate intergenerational inequities (this is the case if χ is close to unity while the variance of χ_i and β_i is high), poor old generations gain at the expense of rich young generations (see Fig. 2).

5. Macro-economic implications of tax reforms

This section explores the macro-economic implications of policy reforms. It focuses on the impacts on aggregate saving and net foreign assets.

5.1. Saving and net foreign assets

Net foreign assets are given by

$$F(t) = A(t) - K(t) \tag{55}$$

where $F(t)$ and $K(t)$ represent, respectively, net foreign wealth and the physical capital stock, all as a share of the aggregate stock of human capital. The ratio of physical and human capital, $K(t)$, is fixed by the rate of return on world capital markets. The effects on financial wealth can be solved from Eqs. (25) and (31):

$$\begin{bmatrix} \dot{C}(t) \\ \dot{A}(t) \end{bmatrix} = \begin{bmatrix} r+\eta-n-\gamma & -\gamma\eta \\ -1 & r-n \end{bmatrix} \cdot \begin{bmatrix} C(t) \\ A(t) \end{bmatrix} + \begin{bmatrix} -\gamma\eta(1-\delta)(1-\chi) & 0 \\ \psi & 1 \end{bmatrix} \cdot \begin{bmatrix} Z \\ \theta \end{bmatrix}. \tag{56}$$

Stability requires

$$\gamma - r + n > 0. \tag{57}$$

This condition keeps the ratio of consumption and human capital, C, bounded by requiring that the rate at which individual consumption rises ($(1/\sigma)(r-\rho) = \mathrm{r} + \eta - \gamma$, see Eq. (9)) is smaller than the sum of the growth of human capital n and the rate at which the share of a generation in the total population declines (i.e. the death rate η).

We find the steady-state effects on financial assets, $A(\infty)$, by setting the left-hand side of Eq. (56) equal to zero and using Eq. (42) to eliminate Z:

$$A(\infty) = \frac{\psi-\gamma}{\psi}\frac{(1-T)(1-x)w}{\gamma-r+n} + \left(\frac{\eta}{\gamma-r+n} - 1\right)\frac{\theta}{r+\eta-n}. \tag{58}$$

In principle, households in a small open economy may own negative financial capital. In that case, both the domestic capital stock and net household debt would be financed by foreign debt (see Eq. (55)). In this paper, however, we assume that households hold positive financial assets by requiring $\psi > \gamma$. This condition ensures that, compared to individual labor income, individual consumption rises faster so that households need to accumulate financial assets (i.e. $(1/\sigma)(r-\rho) > g_\omega$). Moreover, it implies that, with positive lump-sum transfers, the second term at the right-hand side of Eq. (58) is positive as well. Intuitively, for the purpose of consumption smoothing, households save more out of transfers than out of wage income because transfers grow slower than after-tax wages do (i.e. $n < g_\omega$).

5.2. Macroeconomic implications of a more progressive tax system

Just as in Section 4.2, we assume that public debt and lump-sum transfers are absent when considering the effects of changes in progressivity. This enables us to abstract from feedback effects of changes in the growth rate on the government budget constraint. In this case, a more progressive tax system (i.e. δ increases while overall tax revenue T is kept at zero) unambiguously raises the ratio of financial to human capital (see Appendix D):

$$\frac{\mathrm{d}A(\infty)}{\mathrm{d}\delta} > 0. \tag{59}$$

The reason for the increase in the relative importance of financial assets is that a more progressive tax system reduces the growth rate of labor income both directly (i.e. through the direct effect of progressivity) and indirectly (i.e. through the induced adverse effect on the growth rate). Moreover, the adverse impact on growth reduces the rate at which transfer incomes increase. Whereas the growth rate of non-capital incomes thus declines, the growth rate of consumption is unaffected since the rate of return is fixed by the world capital market (see Eq. (9)). The increasing gap between the desired growth of consumption and the actual growth of labor and transfer incomes induces households to save more.

An alternative interpretation for the increase in savings is the intergenerational distribution induced by a more progressive tax system. In particular, a more progressive tax system redistributes income from the rich to the poor, i.e., from current to future generations (see Section 4.2 and, in particular, Eq. (46)). The transfer of resources away from current generations reduces aggregate consumption, thereby boosting saving. The increase in A typically strengthens the net foreign asset position. In particular, if net foreign assets are zero in the initial equilibrium (i.e. $A(t)=K(t)$, see Eq. (55)), a more progressive tax system turns the trade balance initially into surplus, thereby allowing the economy to accumulate net foreign assets.

5.3. *Macroeconomic implications of transfers financed by wage taxation*

To find the impact of changes in lump-sum transfers, we eliminate the aggregate tax rate from Eq. (58) by using Eq. (50) to arrive at:

$$\frac{\mathrm{d}A(\infty)}{\mathrm{d}\theta} = \frac{\gamma}{\gamma - r + n}\,\frac{\eta(1-\delta)(1-\chi)}{\psi(r+\eta-n)}. \tag{60}$$

Although lump-sum transfers do not affect growth (see Section 3), they nevertheless do generate macroeconomic effects by affecting the intergenerational distribution (see Section 4.3). In particular, higher transfers raise economy-wide saving, thereby improving the net foreign asset position. Intuitively, lump-sum transfers redistribute income away from current to future generations (see in particular Eqs. (53) and (54)). The capital loss suffered by current generations reduces aggregate consumption at the time of the policy shock, thereby boosting aggregate saving. Only if all generations collect the same after-tax labor incomes (due to either a uniform distribution of before-tax labor incomes, i.e., $\chi=1$, or a progressive tax system that eliminates all differences in before-tax labor incomes, i.e., $\delta=1$) or if overlapping generations are absent (i.e. $\eta=0$), does the introduction of lump-sum transfers fail to generate any macroeconomic effects.

The boost to saving can be interpreted also in terms of consumption smoothing. In particular, compared to after-tax labor incomes, transfers grow at a slower rate (i.e. $n < g_\omega = n + \eta(1-\delta)(1-\chi)$). Hence, raising the share of transfers in non-capital incomes slows down the overall growth rate of these incomes. To maintain their growth rate of consumption, households thus save more.

6. Conclusions

This paper has stressed the intergenerational spillovers associated with human capital accumulation. We found that, by harming growth, progressive taxes exacerbate the market failures associated with these externalities. A learning subsidy would be one way to internalize these externalities. However, this instrument is difficult to monitor and suffers from moral hazard. As an alternative instrument, regressive taxes help to internalize intergenerational externalities. Even though regressive taxes widen income disparities within any generation, the associated boost to growth benefits the poorest households among generations that are born far into the future. However, regressive taxes hurt the poorer households that are alive when the tax system is changed. Whereas these households suffer from less intragenerational redistribution, they fail to reap any welfare gains from the improved growth performance because higher growth does not affect the human capital they inherited in the past.

Bovenberg and van Ewijk (1995) explore whether, starting from an equilibrium without any government intervention (i.e. $T=\delta=\theta=0$), the government can employ complementary instruments aimed at redistributing the efficiency gains across generations so that all households benefit. In particular, they show that public debt policy allows the government to transfer efficiency gains away from the future to the current generations, thereby increasing the scope for a Pareto-improving reform. Intuitively, by leaving a larger stock of public debt to future generations, who reap the growth benefits from a more regressive tax system, these generations compensate younger current generations, who bear the costs of such a tax reform. In the presence of intragenerational heterogeneity, a regressive tax system affects also the distribution within each generation. Accordingly, heterogeneity within generations unambiguously makes a Pareto improving policy reform more difficult to obtain.

The analysis in this paper can be extended to a closed economy. In the open-economy model developed in this paper, a more progressive tax system hurts growth but raises saving. In a closed economy, this boost to saving would, by reducing interest rates, help to offset the direct adverse effect on growth. Another worthwhile extension would be to incorporate unemployment among the poor due the existence of welfare benefits and to allow for loss of skills during unemployment. In that case, a more progressive tax system might actually enhance growth by improving the employment prospects of the low skilled.

Acknowledgments

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Appendix A

Individual equilibrium

Using Eqs. (1)–(3), we can write the Hamiltonian for the individual problem as (suppressing the time and generation indices t and v)

$$\mathcal{H}_i = \frac{1}{1-\sigma} c_i^{1-\sigma} + \mu_1[(r+\eta)a_i + (1-x_i)\omega_i h_i + \theta H - c_i] + \mu_2 h_i \phi(x_i). \tag{A.1}$$

This yields the first-order conditions

$$c_i^{-\sigma} = \mu_1$$

$$\mu_2 \phi'(x_i) = \mu_1 (1-\delta)\omega_i$$

$$\dot{\mu}_1 = (\rho - r)\mu_1$$

$$\dot{\mu}_2 = \mu_2(\rho + \eta - \phi(x_i) - (1-x)\phi'(x_i)). \tag{A.2}$$

These results can be reduced to Eqs. (9)–(11) by defining $(1-\delta)m_i$ as the *marginal* value of an additional unit of human capital in terms of consumption goods:

$$(1-\delta)m_i(v,t) \equiv \frac{\mu_2(v,t)}{\mu_1(v,t)} \tag{A.3}$$

$m_i(v,t)$ can be interpreted also as the present value of after-tax wage income, i.e., as the *average* value of human capital. To see this, we use Eq. (10) to eliminate $\phi'(x)$ in Eq. (11), and solve for

$$m_i(v,t) = \int_t^{\infty} \omega_i(v,s)(1 - x_i(v,s))\, e^{-\int_t^s r+\eta-g_i(v,u)\,\mathrm{d}u}\, \mathrm{d}s. \tag{A.4}$$

Finally, using (from Eq. (2)) $h_i(v,s) = h_i(v,t) \cdot \exp[\int_t^s g_i(v,u)\mathrm{d}u]$, we obtain

$$m_i(v,t) = \frac{1}{h_i(v,t)} \int_t^{\infty} \omega_i(v,s)(1 - x_i(v,s))h_i(v,s)\, e^{-\int_t^s (r(u)+\eta)\,\mathrm{d}u}\, \mathrm{d}s. \tag{A.5}$$

Appendix B

Aggregate consumption

For each individual household, the intertemporal budget constraint requires:

$$V_i(v,t) = \int_t^{\infty} c_i(v,s)\, e^{-\int_t^s r(u)+\eta\,\mathrm{d}u}\, \mathrm{d}s \tag{B.1}$$

where $V_i(v,t)$ is the individual's total wealth. Using the first-order condition for consumption growth (Eq. (9)) and the constancy of the interest rate, we find:

$$\gamma = \frac{c_i(v,t)}{V_i(v,t)} = r + \eta - \frac{1}{\sigma}(r - \rho). \tag{B.2}$$

This consumption–wealth ratio is thus uniform across households, and therefore represents the aggregate ratio between consumption and wealth.

Appendix C

Distributive effect of progression

Individual wealth of present generations Eq. (36) can be written (using Eqs. (38) and (42) to eliminate $\Omega_i(v,t)$ and $Z(t)$), respectively) as

$$\begin{aligned} V_i(v,t) = {} & \frac{a_i(v,t)}{H(t)} \\ & + (\chi + \delta - \chi\delta)\beta_i\, e^{\eta(1-\delta)(1-\chi)(t-v)}\, \frac{(1-T)(1-x)w}{r+\eta-n-\eta(1-\delta)(1-\chi)} \\ & + \Theta \end{aligned} \tag{C.1}$$

$\mathrm{d}n/\mathrm{d}\delta = \phi'\ \mathrm{d}x/\mathrm{d}\delta$ yields no first order effect on $Z = (1-T)(1-x)w/\psi$ because

$$\left(\frac{\partial Z}{\partial x}/Z\right)=\left[\frac{\phi'}{\psi}-\frac{1}{1-x}\right]=0 \tag{C.2}$$

where the second equality follows from private arbitrage. Using Eq. (C.2), we find that the derivative of Eq. (C.1) with respect to δ yields Eq. (44). In an analogous way, we find Eq. (47) from Eqs. (40) and (41).

Appendix D

Macroeconomic impact of progression

Differentiation of Eq. (58) for $T=\theta=0$ gives:

$$\frac{\mathrm{d}A^{SS}}{\mathrm{d}\delta}=\frac{\eta(1-\chi)}{\gamma-r+n}\,\frac{(1-x)w}{\psi}\left[\frac{\gamma}{\psi}+\frac{\psi(\psi+\gamma-r+n)}{\sigma_g(\gamma-r+n)}\right] \tag{D.1}$$

where we have used $\partial z/\partial n=0$ (from private arbitrage, see Eq. (C.2)). Eq. (D.1) is unambiguously positive, since $\gamma-r+n>0$ (see Eq. (57)).

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